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ECOLOGY OF THE HALOPHILIC VEGETATION OF THE PANNONICUM VI. EFFECT OF THE SOIL-ECOLOGICAL FACTORS ON THE VEGETATION OF THE RESERVE OF LAKE "DONGÉR" AT PUSZTASZER

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Lake "Dongér" at Pusztaszer is a natron lake, lying about 35 km north of Szeged, developed as a consequence of wind and inland-water erosion, with shallow water that periodically becomes dry. Its formation has also been influenced considerably by the inundations of the river Tisza. Since the regularization of river ways its water supply is ensured mainly by the spring inland waters. The overflow is generally drawn through the Dongér-canal.

Shape and size of the lake differred in the past considerably from those to-day. Its arms, bays have changed into salt marshlands owing to the siltation. The siltation of its western part was precipitated by the aeolian sand movement of the Holocene period. The soil-ecological circumstances have consequently rendered possible the production of extremely varied halophilic and glycophilic biocoenoses. Therefore, it proved to be very suitable to perform alkali-investigations of complex character. The team performing a complex investigation of natron lakes in the Hungarian Plain has carried out here systematically zoological, botanical, bioclimatologic and geological investigations since 1965. Owing to the biological values revealed in the course of years it became necessary to declare the lake Dongér and its immediate environs a nature conservation area. After five years, apart from other branches of investigation, the geobotanical—synecological conditions, as well, begin to give a definitive picture. We want to render account now about the results of our investigations in this direction.

Lake Dongér and its environs have looked very promising for improving the synecolocical knowledge of the halophilic vegetation of the Pannonicum — after offering a brief survey of its typical salt phytocoenoses developed in its solonchak and solonetz (BODROGKÖZY, 1962; 1965a; 1965b; 1965c; 1966). This area is namely lying at the eastern border-line of sandy soils originated from the Danube and rearranged in the Holocene and borders immediately on the inundation area of the Tisza that has an extremely hard sedimentary ground variably saturated with native soda and full of halophilic vegetation (RAPAICS, 1926). The particular hydro-

graphic circumstances as the different degree of the water sweating from the strata along the sharp border-line of the vegetation-cover developed in solonchak and solonetz provided an opportunity to solve several unelucidated problems — mainly concerning soil-ecological and soil-physical factors. In the course of our investigations it was ascertained that — apart from the hydrolgraphic resp. chemical factors of soil — also its physical factors — first of all the distribution according to the size of granules — may have a decisive influence on the composition of grass associations in soils saturated not at all or only in some degree with native soda.

Materials and Methods

The phytocoenologico-synecological investigations of the reserve at the lake Dongér began in the spring of 1965. Besides the systematic surveyings performed resp. repaeted .n various aspects, in July of the year also the exposure of the soil profile of the single pgrass, resp. meadow associations took place. In the course of the laboratory elaboration of the soil samples collected, we have determined the percentage of the total salt content measured on the basis of electric condutivity (SIGMOND's version os WHITNEY-MEANS's method) and, besides the sodic alkalinity, that of calcium carbonate, of organic matter. For clearing up the quality of the water-soluble salts and their quant.-tative distribution in the ground levels, we have performed also the analysis of the watery soil extract, resp. the identification of the changeable kations (bases) of soils. We have measured the moisture content of the soils of various plant associations, as well.

The investigation of the granule-composition of ground, the results of which are reflecting more than anything the physical characteristics of its solid phase, was carried out by applying during the hydrometric procedure an areometer of standard size. We have separated from the evaluation curves and evaluated two sand franctions with a granule diameter of 1,0—0,25 and 0,25—0,05 mm, two silt fractions with that of 0,05—0,01 and 0,01—0,005 mm, as well as two clay fractions with that of 0,005—0,001 and 0,001 mm. The perspicuity of data is promoted by complex graphs. In these we have recorded the percentage of physical sand, the soil character, the six ground fractions, the values of the total salt and soda percent as well as that of moisture content from various depths of the excavated and investigated ground levels.

Results

I. Associations developed under the influence of soils of loose structure under glycophilic and halophilic conditions

The nature conservation area of the lake Dongér is lined to the west in a distance of about one km and half with a hill row of sandy loess soil resp. of sand soil covered with loess. As a result of the rearrangement of its material in an aeolian or fluviatile way, there were formed ridges and berms of sandy mud ground in the western area of the flat in the environs of lake. On them there came about a vegetation cover of hard sand, resp. loess steppe. In their species combinations there take place sporadically also species from which a conclusion can be drawn concerning the existence of ancient forests. Such species are e. g.: *Fragaria collina*, *Thalictrum minus*, etc.

1. *Astragalo-Festucetum rupicolae danubiale* Soó (1939) 1964.

In the western area of the reserve, on the ridges of hills projecting into the flats eroded by inundations, resp. on their slopes. From its species combination we can infer minor biogene effects (mainly pasturing).

Soil Conditions

Its sand soils of chernozem or black-earch character are sandy or light mud of loose structure. Its granule composition, at least in levels A and B, are such that its part to be desilted only rarely surpasses 50 p. c. and in it the silt fraction of 0,05—0,01 mm is dominant. As a consequence of its localization on a high level, the content of soil-moisture is low. The sodium accumulation does not reach the degree of alkalinity.

Vegetation Conditions

Its species combination mostly differs from those described from other areas of the territory between the Danube and Tisza. There are missing in our area the subassociations showing a transition towards *Festucion vaginatae*. As depended upon the relief conditions, there are two subassociations to be separated:

1a — — *poëtosum angustifoliae* Soó 1957

In the higher zone of hill ridges. There develops a double grass level. From its group- resp. association character species there are to be found: *Festuca rupicola, Astragalus austriacus, Chrysopogon gryllus, Agropyron pectinatum.* But there are dominant mainly the *Festuco-Brometea* species from which *Poa angustifolia, Ononis spinosa, Cynodon dactylon* are differential species. A species of *Quercetalia* is: *Thalictrum minus.*

1b — — *caricetosum distantis* (Nova subass.)

On the slopes of lower relief of the hill ridges where the ecological effect of the temporarily high subsoil water appears. It is an association indicating the vicinity of subsoil water; in this way, it shows a transition towards *Agrosti-Caricetum distantis* (Rapaics, 1927) Soó 1930. — The number of its group-, resp. association, character species is decreasing. There is a similar situation also concerning the *Festuco-Brometea* species. Instead of them, number and dominance value of the *Arrhenatherion*, resp. *Molinio-Arrhenatheretea* species is increasing. There enter; *Alopecurus pratensis, Trifolium repens, Centaurium minus, Trifolium pratense, Knautia arvensis.* Its differential species is: *Carex distans.*

2. *Potentillo-Festucetum pseudovinae danubiale* Bodrogk. 1959

It is a pasture association, developed in the south-western area of the reserve, on ridges of hills protruding or forming islands, under relief conditions that are similar to the former ones. The adjacent farms are here nearer, the grazing of sheep and small livestock is therefore increased. It may be supposed that *Astragalo-Festucetum rupicolae* used to be here the dominant grass association.

Soil Conditions

They are similar to the soil of the former association, consisting mainly of a sand ground of chernozem character. Its sand fraction is somewhat higher than that demonstrated there (50 to 60 p. c.).

The layers of soil profiles investigated here can, therefore, be considered as a light and sandy mud soil (Fig. 1). The total salt amount, accumulated by absorption of the inland waters that from time to time inundate this zone, reaches 0,1 percent only in the lower strata, and the soda alkalinity 0,05 percent. In this way, even the lower strata cannot be considered as sodic ones. It is therefore easy to understand that there does not take place even a single euhalophilic species in its coenoses.

Conditions of its associations

Its species combination, aspect-changes largely coincide with those described from other regions between the Danube and Tisza (BODROGKÖZY, 1959). From the species *Festucion rupicolae*, resp. *Festucetalia valesiacae* it is worth while mentioning: *Stipa capillata*, *Silene otites* ssp. *pseudotites*, *Verbascum phoeniceum*, *Echium italicum*, etc.

2a — — *cynodontetosum* Soó 1955

The mass multiplication of some *Festuco-Brometea* species as differential species can be considered as a result of an increased zoogene effect. This subasociation is, therefore, very frequent in our area.

The facies may be formed in areas, less exposed to pasturage and treading, by *Filipendula vulgaris*, in other areas by *Stipa capillata*.

2b — — *caricetosum distantis* BODROGK. 1959

The subassociation is also here of subsoil-indicating character, similarly to the former association.

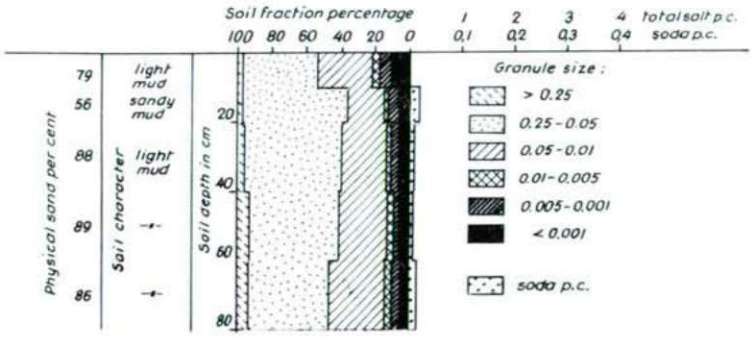

Fig. 1. Profile No. 8 of the light mud-soil of *Potentillo-Festucetum pseudovinae*.

3. *Artemisio-Festucetum pseudovinae danubiale* Soó 1963

This association is generally known as an artemisia steppe of solonetz, in the Hungarian Plain and particularly in the territory east of the river Tisza. Its occurrence in the territory between the Danube and Tisza may be presumed only from MOESZ's data (1940). Our recent investigations have confirmed Soó's effort (1964) to separate its phytocoenoses from those in the territory east of the river Tisza at least as a geographic variant.

Its species combinations to be found in the reserve at the lake Dongér are somewhat differring from those published from the western area of the territory between the rivers Danube and Tisza.

Soil conditions

Artemisio-Festucetum pseudovinae is, as to its localization, similarly zonal. It occurs under the zones of the former two associations, on lower hill ridges and

berms where the soil water is, mainly in the spring period, rather high, owing to the continuous flux of layer water (Fig. 2).

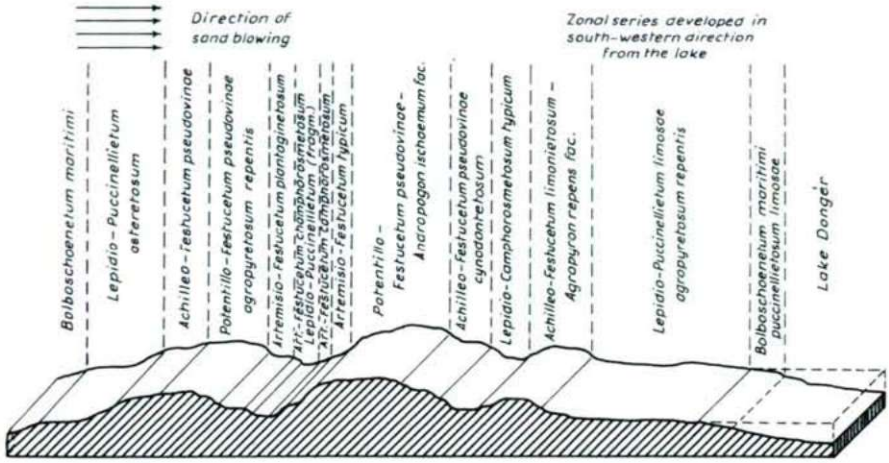

Fig. 2. Zonal arrangement of the subassociations of *Artemisio-Festucetum* (Nov. 2nd 1968), west of the lake Dongér.

Sodaic alkalinity can be demonstrated already from the soil surface. The salt movement is important even in the vegetation period; at the same time, in the profiles the separation of the single strata can already be observed well. We have here, therefore, solonchak — solonetz. For characterizing, we are presenting soil profile No. 11. Owing to the eluviation in soils, its A-level has but a minimum sodium-salt content so that even some glycophytic species having not deep roots may obtain a considerable participation in covering. In the B_2-level there is, however, already a considerable content of soda (0,2 to 0,3 percent) and of total salt (2,0 to 2,5 percent) (Fig. 3).

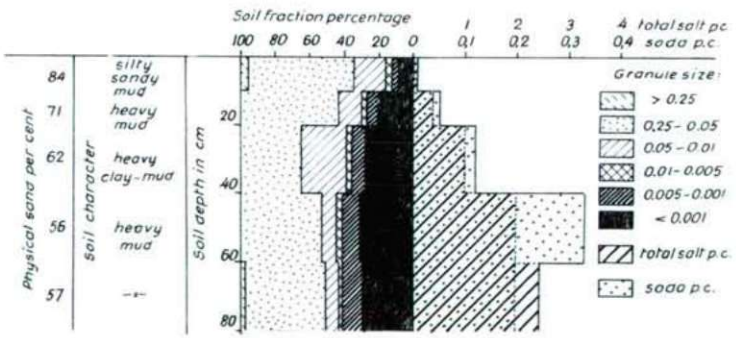

Fig. 3. Soil profile No. 11 of *Artemisio-Festucetum*

Association conditions

The peculiar combination of the glycophilic and halophilic species is characteristic of its species combinations, as generally observed in case of *Artemisio-Festucetum*. The appearance of the not deeply rooted *Festuca pseudovina* var. *salina*, *Achillea collina*, *Bromus mollis*, *Poa bulbosa* v. *vivipara*, *Trifolium campestre*, *Cynodon dactylon*, *Trifolium arvense* that are dominant in the eluviated A-level, is indicative of the insufficiency of calcium carbonate in that layer.

The components *Festucion pseudovinae* and *Festuco-Puccinellietea*, as well as *Artemisia monogyna* ssp. *salina*, *Limonium gmelini*, *Podospermum canum* are indicating the high alkaline values of level B. — The most important thing for us is, however, the appearance of the characteristic species of the geographical variant of association, *Plantago maritima* and *P. schwarzenbergiana*. They are indicative of solonchak — solonetz of low slack-water content, ensuring due water supply, coming into being in a sandy mud soil of a higher salt and soda content in its B-level.

3a — — *plantaginetosum maritimae* (Nova subass.)

As a typical subassociation, it is the most wide-spread in our area. *Plantago maritima* and *P. schwarzenbergiana* can be regarded as its differential species.
Facies: *Achillea collina* in eluviated solonchak — solonetz of A-level that may be called a mediocre steppe.
Facies: *Camphorosma annua*

It occurs in case of minor superficial erosions in the zone of the association if the solonchak-solonetz strata get to the neighbourhood of surface or the sodium salts are washed together into these depressions. As a result of that, some *Festuco-Puccinellietalia*, resp. *Puccinellion* components may occur as *Cerastium dubium*, *Lepidium perfoliatum*, at some other time *Puccinellia distans ssp. limosa*; *Camphorosma annua* having, anyway, the greatest participation in covering. It is showing a transition towards *Lepidio-Camphorosmetum festucetosum pseudovinae*.

4. *Lepidio-Camphorosmetum annuae* (RAPAICS 1927) Soó 1957

It occurs in the western area of the reserve, on the bottom of hill ridges and berm-like protrusions in the third zone that follows the direction of the relief settlement where, as a result of water erosion, the stratum of salt accumulation in the solonetz level got to the surface (Fig. 4). It is forming long stripes running zigzag, following the meanders of the zone. The extent of its substance in our area is, anyway, not considerable.

Soil ecology

The surface layers of its solonchak formed in a sand ground of chernozem character are containing 40—50 percent desiltable fraction, about 50 p. c. of which being made of two clay fractions with granule diameters of 0,005 to 0,001 and $<0{,}001$ mm. The lower layers are somewhat harder, and the medium mud turns into a heavy clay-mud soil (Fig. 5).

The movement of sodium salts is considerable, the surface accumulation in spring can be found in July in layers of 10 to 40 cm depth. Both the soda alkalinity and the percentage of total salt are extremely high; at the same time, the soil moistuer on the soil surface was in July hardly 5 percent (Fig. 5).

Vegetation conditions

The phytocoenological question, where the substances of *Lepidio-Camphorosmetum annuae* belong to, cannot be always decided easily. Because of the extreme habitat conditions the species number is low enough. In the border-area of the geographical distribution of the association important character species are missing.

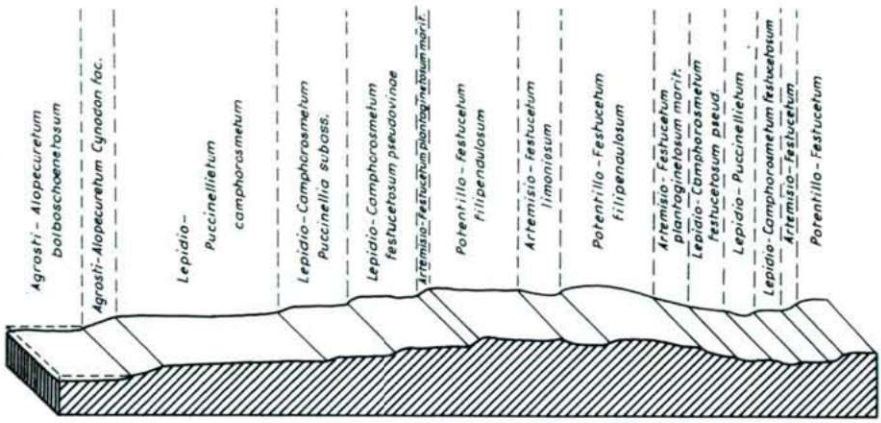

Fig. 4. Zone conditions of *Lepidio-Camphorosmetum annuae* in thewsətern area of the reserve (November 2nd 1968).

Thus the typical solonchak species, *Plantago maritima*, is often substitutes for another species, *Lepidium crassifolium*. As depended upon the ecological conditions of ground, there can be separated more associations of its:

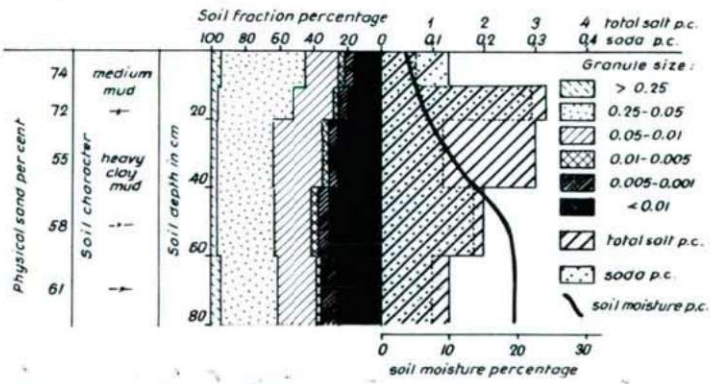

Fig. 5. Soil profile No. 2 of *Lepidio-Camphorosmetum* (Cf. explanatory note in Fig. 3).

4a — — *lepidietosum crassifolii (typicum)* (Nomen novum).

In the highest area of the zone of association where the influence of subsoil water may still be considerable but the surface is covered by water only for a short time. The highest salt concentration of Hungarian licks is to be observed consequently in this place. In the reserve, at any rate, it can be noticed only in smaller spots.

Its facies is: *Plantago maritima.*

4b — — *puccinellietosum limosae* BODROGK. 1962

In the lower area of the zone of the association. It often shows a transition towards *Lepidio-Puccinellietum*. As a resu t of the higher water content, resp. lower salt concentration of soil, there occur as differential species: *Puccinellia limosa, Plantago schwarzenbergiana, Lepidium perfoliatum.*

Puccinellia limosa, Plantago maritima are facies-forming.

4c — — *festucetosum pseudovinae* BODROGK. 1962

As a consequence o the erosive activity o the rainwater accumulated in the depressions of lower hill r dges and berm zones, there were formed bowl- or basin-like dips of 1—5 sq. m extent. In them sodium salts got to the surface. In this way, the *Camphorosma* facies of *Artemisio-Festucetum pseudovinae* has changed into a subassociation of that association. While the phytocoenoses 4a and 4b take place in the zone providing for them the optimum of habitat conditions, the subassociation *Festuca pseudovina* is showing an extrazonal appearance (Fig. 4). Although the amount of sodium salts does not reach the quantity demonstrated in case of 4a this may be considered as the most extreme habitat of *Lepidio-Camphorosmetum* The soil moisture that has diminished more and more, is namely increasing the physiological efficiency of sodium salts. The ground frequently becomes a soloth.

5. *Lepidio-Puccinellietum limosae* (TOPA 1939) SOÓ 1957

Following the further depression of relief in the western area of our territory, we get to the upper zone of smaller or larger back-water areas, so-called flats among the ridges of hills (with an extension from some 100 sq. m to more ha's) (Fig. 6). These are covered by the spring inland water for a longer time and also the subsoil water is nearer to the surface.

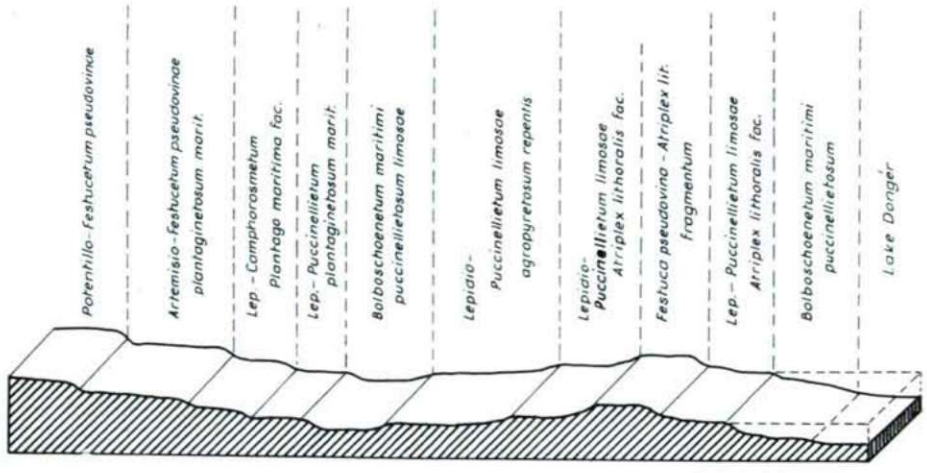

Fig. 6. Zonation of the subassociation of *Lepidio-Puccinellietum* at the western shore of the lake Dongér

Soil-ecological conditions

The excavated and investigated soil profiles differ from those of soils in the territories between the Danube and Tisza both in the respect of their physical composition and of their chemical characteristics. Evaluating the results of the investigations in its profile No. 1, we can ascertain that in that zone the degree of sand blow, resp. covering with sand does not at all reach the degree observed at the soils of *Lepidio-Camphorosmetum*. Concerning its soil fractions, the desiltable part reaches the 80 percent already on the surface and from that more than 50 percent falls to the two clay fractions.

From chemical point of view, the sodium salts don't accumulate even in the summer aspect in a soil level higher than 40 to 60 cm. For the combination of vegetation, first of all the influence of surface layers is decisive. However high may be the percentage of soda alkalinity and total salt here too, it is highly compensated by the favourable hydrographic conditions in the summer months, as well. The moisture content of soil on the surface reaches 25 percent even in July (Fig. 7). It can be explained with that that besides the expressedly halophilic species there occur also glycophilic species as: *Typha angustifolia, Alisma lanceolatum, Agrostis alba.*

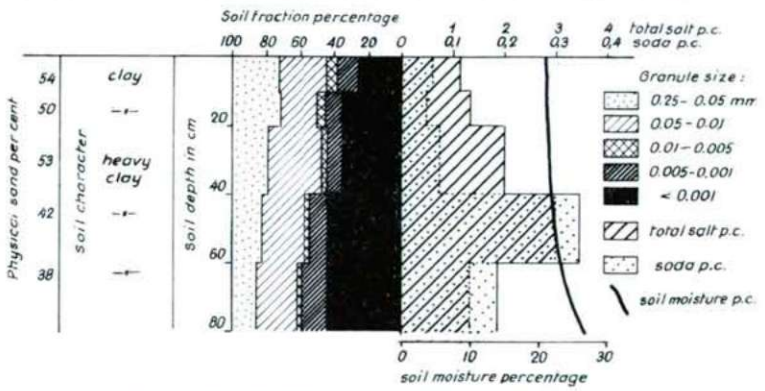

Fig. 7. Soil profile No. 1 of *Lepidio-Puccinellietum*

Association conditions

Depending on the physical, chemical and hydrographic characters of the soil levels lying near the surface, there develop highly varied species combinations on our area, too. By means of differential species, the following subassociations could be separated:

5a — — *camphorosmetosum* (Moesz) 1940 Soó 1957

It shows a transition towards the former association both from the point of view of soil ecology and that of phytocoenology. In our area it is, consequently, not important: but it forms sporadically wider zones than *Lepidio-Camphorosmetum* (Fig. 4).

5b — — *puccinellietosum (typicum)* Soó 1964

It is under more favourable hydrographic conditions than the former one. Its habitat is covered with shallow water in a great part of the vegetation period.

In the summer and autumn aspects, there occur in its species combinations alkaline silt-plant species as *Plantago tenuifolia, Myosurus minimus*. The covering value of *Nostoc commune* is considerable. At the same time, there are still missing: *Aster tripolium* ssp. *pannonicus, Eleocharis uniglumis, Agrostis alba, Juncus compressus.*

Puccinellia limosa develops sporadically pure substances. Other species occur only blade by blade.

Here, in the borderland of the distribution of *Lepidio-Puccinellietum*, it is often difficult to separate it from the species combinations of the *Puccinellietum limosae hungaricum* (RAPAICS 1927) SOÓ 1930 in the hard soil territory east of the river Tisza what can be explained first of all by the harder structure of its soil as compared with that of the territory between the Danube and Tisza.

5c — — *asteretosum pannonici* BODROGK. 1962

Its soil ecological conditions are considerably more favourable than that of the type: besides similar water supply, the soda, resp. total salt content on the surface of soil is diminished. Its phytocoenoses are, consequently, richer in species, first of all the *Agrostion albae* species occur, similarly to other regions of the territory between the Danube and Tisza (BODROGKÖZY, 1962).

Juncus compressus, that here can be considered as a vicarious species of *J. gerardi*, is facies-forming.

Plantago tenuifolia may be facies-forming, as well. In case of the formation of a rain maximum in a rainy spring or June, an alkaline silt vegetation develops.

5d — — *agropyretosum repentis* (Nova subass.)

Its species combination is fu ly unaccustomed in *Lepidio-Puccinellietum*. Its stands are of double level. Its upper grass level is formed by *Agropyron repens, Rumex stenophyllus, Bolboschoenus maritimus* and the lower one by *Puccinellia limosa, Aster tripolium* ssp. *pannonicus, Alisma lanceolatum, Eleocharis uniglumis.* Its soil is differring from that of *Lepidio-Puccinellietum* of typical appearance, being near to the meadow solonetz where the A-level is eluviated so much that only a minimum of soda alcalinity and total salt amount can be demonstrated. Below ten cm, however, their value — particularly that of soda alkalinity — quickly increases. Accordingly, the glycophilic *Agropyron* uses the upper ten cm soil layer. Also the continuous layer-water supply of the subsoil from the direction of sand ridges is of compensating influence.

5e — — *juncetosum ranarii* (Nova subass.)

We have found recently in the middle area of the territory between the Danube and Tisza, among alkaline silt associations, in more places, *Juncus bufonius* ssp. *ranarius*. Previously, it was only known from the area of the lakes Fertõ and Balaton (SOÓ—JÁVORKA, 1951; SOÓ—KÁRPÁTI, 1968). Supposedly, it has got by means of birds into the zone immediately at the shore of the lake Dong r, as well. In our area it is not only a participant of a silt association. In the species combination at the shore of the lake *Lepidio-Puccinellietum* is occurring as a differential species together with *Plantago tenuifolia.*

In its soil profile excavated, in the ten cm layer on the surface, the desiltable fraction is lower than 50 percent, with low soda and total salt content. In the deeper soil strata, clay soil is substituted for the covering sand.

6. *Festucetum pratensis hungaricum* Soó (1938) 1955

It occurs along the western border-line of the reserve at the lake Dongér — immediately in the neighbourhood of the cultivated areas, in the deepest zone of the flat where a standing water supply is ensured by the oozing layer water. In this way, in our area it can be considered as an expressedly glycophilic association.

6a — — *caricetosum vulpinae* (Nova subass.)

It can be found in the areas covered with water for the longest time, together with *Agrostis alba, Eleocharis palustris,* as well as with other *Molinion, Molinietalia,* and *Molinio-Arrhenatheretea* species. Facies-forming is: *Dactylis glomerata,* in the rather dry areas. In its species combinations it occurs with the *Molinio-Arrhenatheretea,* resp. *Festuco-Brometea* species.

II. Plant associations developed in hard soils

East of the lake Dongér, both the soil ecological and the phytocoenological conditions are showing a very strong contrast as compared to the former ones. The wind-blown sand is here already only of minimum effect. In this way, in the area inundated by the Tisza, one of the hardest meadows, resp. solonetz of the Hungarian Plain could come into being. Their covering vegetation sharply differs from those described in the area a few hundred metres farther in the west of the lake. The differences arisen from the physical structure of soil are highly emphasized also by that the eastern part is no more influenced considerably by the layer waters oozing from the direction of the western border of the reserve. The level of subsoil water is consequently lying deep and the water cannot be utilized at all by the vegetation or only with difficulty.

The relief differences that develop the zonation conditions of the single plant associations do not reach at all those established in a loose soil. Starting from the highest zone, the following phytocoenoses could be identified:

7. *Achilleo-Festucetum pseudovinae* (Magyar 1928) Soó 1945

It is a glycophilic coenosis formed on ridges of chernozem soil with comparatively higher relief level and inundated by inland waters only scarcely. It is to be supposed that before the arrangement of inland waters, there were dominant more favourable hydrographic conditions in this higher zone, as well. This is referred to also by the *Agrostion,* resp. *Molinietalia* species being sporadically present even in our days.

Its soil ecological conditions:

It is to be mentioned for characterizing physically its chernozem soil that the so-called desiltable part of a granule size smaller than 0.05 mm is exceeding 60 percent even in level A_1 (0 to 10 cm). Increasing evenly in the direction of lower levels, under 40 cm this value is 90 percent. The amount of the two clay fractions (with a granule diameter of 0,005—0,001, resp. <0,001 mm) is higher than 50 percent of the desiltable part (Fig. 8).

According to the results of chemical analysis, there could not be demonstrated any content of total salt, resp. soda of a considerable amount in the A-level (0 to 20 cm).

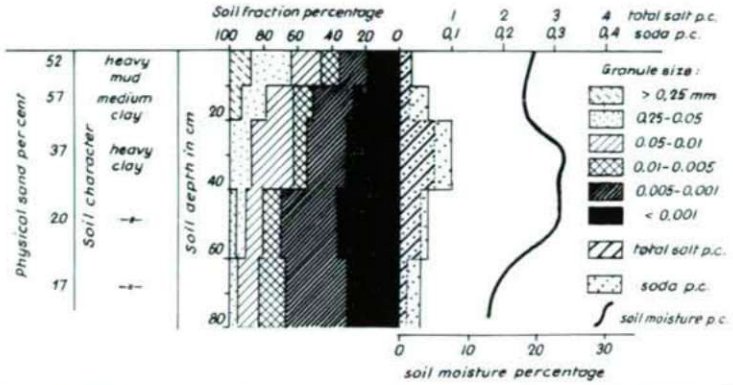

Fig. 8. Soil profile No. 5 of the *Alopecurus pratensis* facies of *Achilleo-Festucetum limonietosum* medium clay

Vegetation covering

Depending on the chemical and hydrographic character of the soil, there could be separated three subassociations in our area.

7a — — *achilleetosum (typicum)* Soó 1964

It is a typical occurrence of the association. The large sheep-runs of the reserve and its environs are formed by this subassociation. As its soil profiles don't contain a larger amount of sodium salts in the deeper layers, either, there occur no halophilic species there — except some pseudohalophilic *Festucion pseudovinae,* resp. *Artemisio-Festucetalia pseudovinae* species. It can be considered, therefore, as a dry pasture of chernozem soil, belonging rather to the *Festucion sulcatae (=rupicolae)* federation. The *Festuco-Brometea,* resp. *Festuco-Bromea* components are dominant.

7b — — *limonietosum* SLAVNIĆ 1948 *(Ranunculetum pedati* subass. *Statice Gmelini)*

In its soil there can already be demonstrated a larger amount of salt, resp. soda, mainly in level B under 20 cm. The chemical composition of its profile is referring to a meadow chernozem soil of solonchak character that is saline in its depth. The glycophilic species without deep roots are not influenced by the 0,02, resp. 0,06 percent soda and 0,04 percent total salt content of level A. The sodium salts accumulated in deeper layers are referred to by the occurrence of *Limonium gmelini* as differential species. This subassociation is present as a transitory species combination in the border zone of the sometime extensive *Achilleo-Festucetum pseudovinae* bordering on soils saturated with native soda. In the dry pastures with sand grounds of chernozem character between the Danube and Tisza, there may develop a border zone similar to *Potentillo-Festucetum pseudovinae* (BODROGKÖZY, 1962), without considering this type of pastures as a saline pasture.

Facies: *Alopecurus pratensis.* In our area under rather favourable hydrographic conditions it is fairly frequent. Its detailed soil ecological characteristics may be observed in Fig. 8.

8. *Artemisio-Festucetum pseudovinae pannonicum* Soó 1963

The immense artemisia-steppes of the licks east of the river Tisza that are formed on a meadow solonetz extend as far as the eastern area of the reserve at the

lake Dongér. The high slack-water content of their meadow clay soil and the high values of the accumulated sodium salts are connected with a rather low soil-moisture content. Therefore, we can understand the poverty of species that generally characterizes these solonetz steppe meadows. Their general phytocoenologico-synecological characterization is known partly from the classical habitat, Hortobágy (MAGYAR, 1928, 1930; Soó, 1934; SZABOLCS, 1954; BODROGKÖZY, 1965a), partly from the solonetz of the Ancient-Maros-valley (BODROGKÖZY, 1966). At present we want to make known the synecological conditions of its transitory border lands.

Soil-ecological conditions

As to the physical structure of its excavated soil profiles, it proved to be considerably harder than it was known so far. The desiltable fraction of granule diameters smaller than 0,05 mm approaches 80 percent already in level A. One-third of that is colloid-like, $<0{,}001$ mm φ. In the columns of the solonetz level B_1, however, it reaches 50 percent of the desiltable part and can, therefore, be considered as heavy clay.

By the means of chemical analysis a transitory character may be established because — as distinguished from those beyond the Tisza — a high soda alkalinity percentage can be demonstrated. In this way, we can ascertain the presence of steppe-like meadow solonetz of solonchak character (Fig. 9). Its sporadic occurrence in the south-eastern region of the territory east of the river Tisza is known (ÁBRAHÁM, 1967).

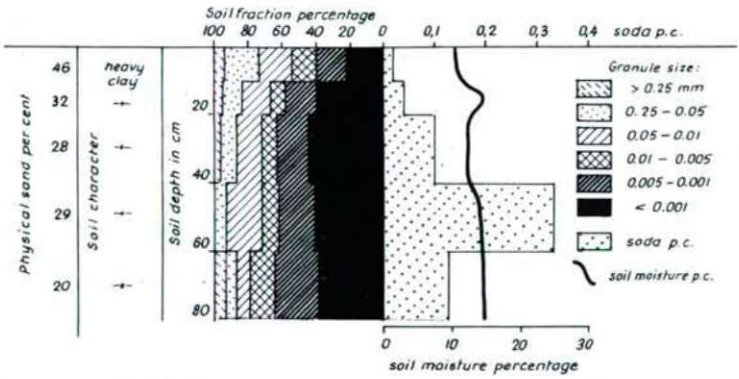

Fig. 9. Soil profile No. 4 of *Artemisio-Festucetum* from the eastern area of the reserve

Association conditions

In its phytocoenoses, apart from the species known from other artemisia steppes, there may occur blade by blade also some species reflecting a solonchak character as *Plantago maritima, P. schwarzenbergiana, Lepidium perfoliatum.* Their mass appearance as facies (RAPAICS, 1927; MOESZ, 1940; Soó, 1947; SLAVNIĆ, 1948) already belongs to the different units of *Artemisio-Festucetum danubiale.*

8a — — *festucetosum pseudovinae (typicum)* (WENDELBG. 1943) Soó 1947

In our area it is insignificant because, besides the group participation of the p ecies inside the class *Festuco-Puccinellietea,* also the spread of some glycophilic

species, first of all of the *Festuco-Brometea* and *Festuco-Bromea* species is considerable.

Facies: *Achillea collina*. In its species combinations with the *Trifolium arvense, Bromus mollis, Trifolium campestre, Poa bulbosa* v. *vivipara* species.

From its appearance we can conclude that the eluviation of A-level is more increased than that of the type. This *Achillea collina* facies generally develops, anyway, in meadow solonetz having a steppe character in the middle and depth.

8b — — *camphorosmetosum* (RAPAICS 1927) WENDELBG. 1943

As a result of the eroding activity of rain water, the soil surface of the artemisia steppes may be submitted to an erosion of such degree that in it bowl- or basin-like depressions can occur where the meadow solonetz layers with solonchak can get on or near the surface. Owing to the impermeable layer formed by heavy clay, the accumulated rain water cannot be absorbed. After drying up of these longlasting slack-water pools, the percentage of the total covering of steppe species decreases. They are substituted for by *Puccinellion limosae* elements — as differential species. With that, the process of formation of extrazonal, secondary berms begins.

9. *Camphorosmetum annuae* (RAPAICS 1916) SOÓ 1933

Its distribution in the area of the reserve is unimportant. Comparing its ecological relations with those investigated in other areas of the territory east of the river Tisza, it can be established that its soil profiles investigated along the Dongér are of heavy clay, its soda alkalinity values, resp. its salt content are higher. The effect of these is, however, compensated in some degree by the more favourable hydrographic conditions. It is to be attributed to that that its species number is higher than observed anywhere else.

10. *Puccinellietum limosae hungaricum* (RAPAICS 1927) SOÓ 1930

The eastern part of the reserve — owing to the harder soil conditions — being less dissected, the halophilic vegetation is giving not at all a varied picture like that observed in the western part. Therefore, the *Puccinellietum* stands of solonetz are found first of all in the bank zones of brooks winding in zigzags, eroded by the Tisza or other inland waters. The solonetz layers are, here too, near to the surface.

These brooks are in rainy years, rich in precipitation, water-covered for a longer time, and the usual *Puccinellietum* species combination is mixed with. *Potamion* species, as well.

Soil ecological conditions

As to its physical composition, it is nearly identical with the soil conditions of *Camphorosmetum*. Accordingly, in level A there can be desilted 80 percent, in level B_1 and B_2 respectively already 90—95 percent, i. e., the fraction is smaller than smaller 0,05 mm granule diameter. Three-fourth of it is then clay with granule size smaller than 0,005 mm (Fig. 10).

Its soil-chemical character is reflected first of all in the change in the amount of sodium salts according to vegetation zones. There is generally afforded an increased solonchak character by the soda alkalinity higher than the accustomed one, resp. by the calcium carbonate content.

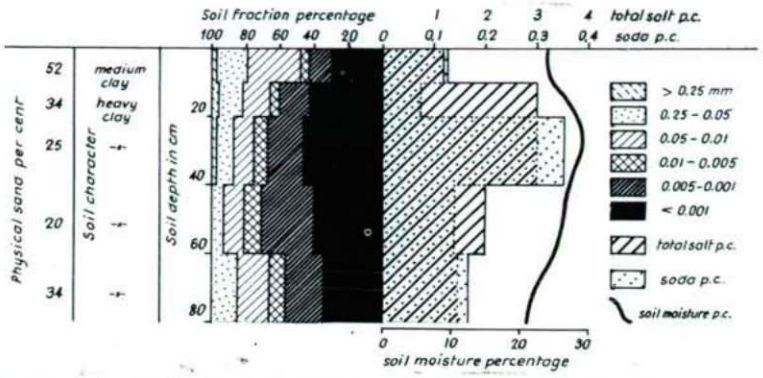

Fig. 10. Results of the physical and chemical investigations of soil profile No. 7 of *Puccinellietum limosae* typicum

Vegetation conditions

The association, corresponding to the relief difference developed by the inland-water erosion, makes possible to separate more zones. The species combination of the single coenoses accordingly changes:

10a — — *puccinellietosum (typicum)* (Nomen novum)

It presents itself in our arae in the high est zone of the association. The complex effect of the chemical and mainly of the hydrographic conditions often results in the development of the *Camphorosma annua* facies (Fig. 11).

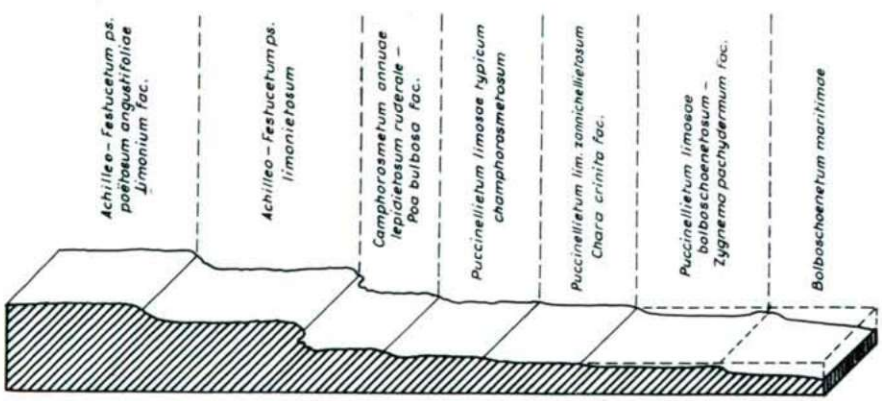

Fig. 11. Zonation conditions of the subassociations of *Puccinellietum limosae* in a flat eroded by inland water, in the eastern area of the reserve.

Its species number is richer than usual. In years of more precipitation the conditions of soil moisture make possible even in this zone the considerable distribution of some alkaline silt plant species as *Plantago tenuiflora*. At the same time,

the accumulation of sodium salts is higher even in the B-level under 10 cm than the usual one. The percentage of the total salt content can reach, e. g., in July 3 p. c. (Fig. 10).

10b — — *zannichellietosum* (Nova subass.)

It develops in the lower zone of the association as the area is covered with water for a longer time — sometimes till July. Its differential species are, apart from *Zanichelia palustris*, facies-forming *Chara crinita* and a particularly large mass of *Zygnema pachydermum* (det. UHERKOVICH), with *Nostoc commune*.

10c — — *bolboschoenetosum*

It forms a transition towards *Bolboschoenetum maritimi* and along the brooks it occupies the deepest zone of the association. In its coenoses, a triple-level distribution takes place: there are in the upper level *Bolboschoenus maritimus, Phragmites communis,* in the central one *Puccinellia, Eleocharis* and in the water zone *Batrachium, Zygnema pachydermum, Chara crinita.*

Facies forming is: *Zygnema pachydermum*

10d — — *agropyretosum repentis* (Nova subass.)

It is distributed first of all in meadow solonetz flats of wide extension. Phytocoenologically it is near to a subassociation of *Lepidio-Puccinellietum* of similar name. Its ground is, as to its physical structure, extremely hard. Three-quarters of the desiltable part coming close to 90 percent is given by the two clay fractions. In the levels B_2 and BC, nearly 60 percent of the soil is afforded by the colloid-like clay fraction of $<0{,}001$ mm granule diameter.

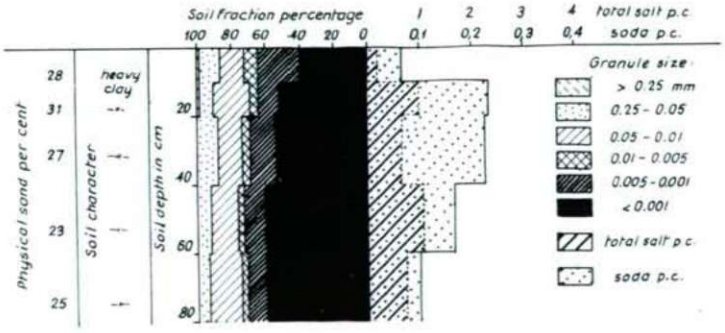

Fig. 12. Soil-ecological conditions of *Puccinellietum limosae agropyretosum (repentis)*, on the basis of laboratory invetigations of soil profile No. 13, resulting from the eastern area.

The A-level of this meadow solonetz, that from chemical point of view is of solonchak character, is eluviated enough in respect of sodium salts. The value of soda alkalinity is, however, — as regards the mass occurrence of the glycophilic *Agropyron repens* — rather high: 0,05 percent and under 10 cm this value quickly increases (Fig. 12). The dominant role of this species can be explained first of all with the compensatory influence of the favourable hydrographic conditions.

In its phytocoenoses there developed a triple grass level. The upper level is composed of *Agropyron repens, Rumex stenophyllus, Bolboschoenus maritimus*; the

middle one of *Puccinellia limosa, Eleocharis uniglumis*; and the lower one of cotyledonous silt-plant species: *Plantago tenuiflora, Pholiurus pannonicus,* resp. *Lotus tenuis.*

11e — — *atriplicetosum litoralis* (Nova subass.)

It occurs in areas along the lake-shore grazed in an increased degree, first of all as a pasture for geese. The effect of sand-blast cannot be seen any more. There was produced here a solonchak meadow where the increased fertilization has resulted in a nitrogen accumulation. In this way, the differential species of the subassociation come from the nitrophilic halophytes as *Atriplex litoralis, Lepidium ruderale, Atriplex hastata* v. *salina.* In addition to these there are often cotyledonous silt plants, mainly *Myosurus minimus, Cerastium dubium, Plantago tenuiflora.*

Facies: *Hordeum hystrix* (first of all on a higher relief level). The soil both of the subassociation and of its facies is similar to that described under 11 d, from both physical and chemical points of view.

12. *Agrosti-Alopecuretum pratensis crisicum* (Nomen novum)

In our area, it is in the flats visited by inland water, immediately beneath the zone of *Puccinellietum limosae.* Depending upon its soil-ecological relations, even more subassociations of its can be separated. These depend first of all on hydrographic factors.

12a — — *alopecuretosum pratensis (typicum)* SLAVNIĆ 1948. In the reserve, the subassociation is less distributed. In its species combinations there occur the characteristic species of the marshy meadows in the territory in the east of the river Tisza, *Rorippa silvestris* ssp. *kerneri, Ranunculus lateriflorus,* etc.

12b — — *agropyretosum repentis* (Nova subass.)

It is the most distributed *Agrosti-Alopecuretum* variant of the area showing that *Agropyron repens* feels very well in these marshy meadows just as the former associations.

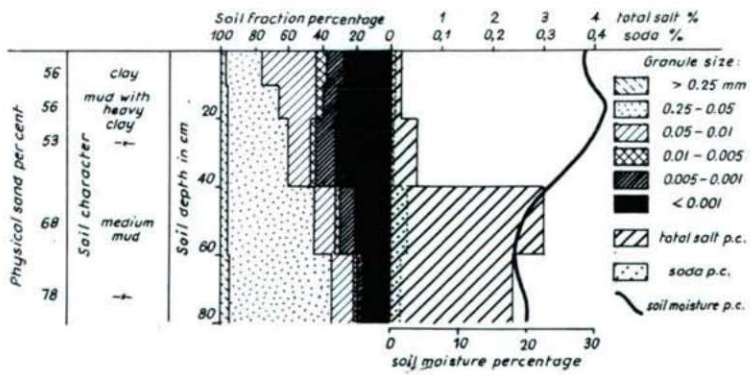

Fig. 13. Soil profile No. 3 of the *Agropyron repens* subassociation of *Agrosti-Alopecuretum pratensis,* from the border-line of the western and eastern areas of the reserve

It could be ascertained in the course of the chemical analysis of its soil that in the reserve at the lake Dongér — just as in the investigated soil profiles originating from other areas of the Hungarian Plain — the total salt percentage is rather important at the most only in the lower layers. The soda content is of minimum quantity (Fig. 13).

This is reflected in the species combination of the subassociation, as well. There does not occur any halophilic species, except some pseudohalophilic ones.

12c — — *poëtosum angustifoliae* (Nova subass.)

In the areas where — owing to the functioning of the Dongér canal — the old marshy meadows had gradually dried up and that process was not followed by alkalization, the hygrophilic species were from year to year more and more substituted for by mezo-, resp. xerophilic species. The first step like that is the transition of *Agrosti-Alopecuretum typicum* into the variant of *Poa angustifolia*.

In its species combinations, *Cynodon dactylon, Carex divulsa, C. stenophylla* and later *Trifolium striatum* play a part. Then in time, either *Cynodonti-Poëtum angustifoliae* or *Achilleo-Festucetum pseudovinae* will develop after the draining being increased.

13. *Agrosti-Beckmannietum* (RAPAICS 1916) SOÓ 1933

This association becomes dominant in the eastern part of the reserve, connected with Crisicum, in the deepest relief of the flats eroded by inland waters where in case of a normal distribution of precipitation the area is watercovered in the most part of the vegetation period.

Soil ecological conditions

The soil development bears first of all the marks of the hydrographic conditions. The colloids of stagnant inland waters have plenty of time for deposing. Consequ-

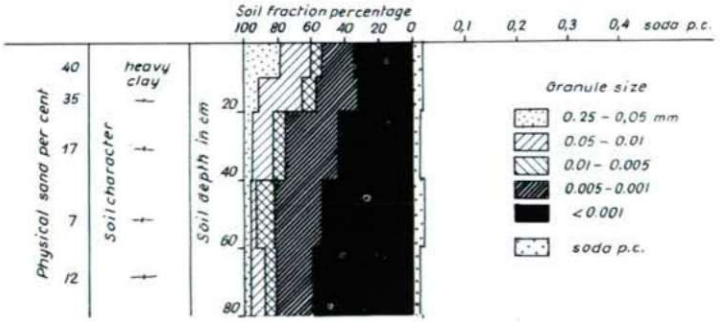

Fig. 14. Soil-ecological conditions of *Beckmannietum eruciformis* on the basis of physical and chemical investigations of soil profile No. 15

ently, in its investigated soil profiles beginning from level B the desiltable part approaches 95 percent and, what is more, these soil strata are built up in 80 percent of the two clay fractions (with granule diameter of 0,005 to 0,001, resp. <0,001 mm).

In the course of the chemical analysis it emerged that it is just as poor in salt and soda as the *Agrosti-Beckmannietum* soils investigated so far in other parts of the Hungarian Plain (Fig. 14).

The development of the species combination of the association is determined first of all by the physical structure and water supply of the ground. It can be explained with that the euhalophilic species have mostly no role at all in these coenoses. In our area, the *Beckmannia eruciformis* of high dominance is associated with *Eleocharis palustris Lythrum virgatum, Mentha pulegium* or blade by blade the elsewhere facies-forming *Bolboschoenus maritimus.*

14. *Bolboschoenetum maritimi continentale* Soó (1927) 1957

It is constituting extensive stands in the zone of the former association, along the shores of the lake Dongér. Depending upon the soil, resp. water conditions, there can also here be separated more subassociations.

14a — — *puccinellietosum limosae* Bodrogk. 1962

In the shore zone of water-covered flats with alkaline soil where this zone is immediately associated with *Lepidio-Puccinellietum* or *Puccinellietum limosae,* it presents itself as a transitory subassociation.

14b — — *crypsidetosum aculeatae* Bodrogk. 1962

The stands of *Bolboschoenetum* beside the shores of the lake Dongér dry up early in dry years. In their lower grass level there develop the differentiated associations of *Crypsis aculeata.* It forms a transition towards the deeper parts of the lake that only dry up for the end of summer, making possible the development of the, *Crypsidetum aculeatae* stands.

Summary

In the present study of the series about the results of the synecological investigation of the halophilic vegetation of the Pannonicum the results of the investigations of the reserve at the lake Dongér for five years are summarized. As the area is at the border of sand soils of chernozem character saturated in different degrees with native soda and of meadow clay soils, it became possible to measure the effect of the physical structure of soil exerted on the halophilic plant associations.

1. If in levels A and B of a sand soil profile of chernozem character there prevails a granule fraction of a diameter smaller than 0,05 mm, the salt concentration is higher than 0,05 percent and the soil-moisture percentage is low, then *Potentillo-Festucetum pseudovinae* is dominant. The species number is high, at any rate without halophilic species. The biogene effect is increased.
2. Under similar soil-ecological conditions, in case of a zoogene effect of smaller degree, *Astragalo-Festucetum rupicolae danubiale* is wide-spread.

Its subassociations are indicating the differences of the hydrographic relations.

3. In case of a similar distribution of the granule fraction if in the soil profiles there take place higher total salt values than 0,05 percent, resp. more considerable soda alkaline values, then we are facing solonchak solonetz approaching the steppe character. In them *Artemisio-Festucetum pseudovinae danubiale* develops. In its species combinations there are: *Plantago maritima* and *P. Schwarzenbergiana.*

In case of a similar physical structure of the soil profile but with a high salt (0,5), resp. soda-alkalinity percentage (0,1), solonchak and possibly solonchak-solonetz appear on the bottom of hill ridges and berms, with low soil-moisture content on the surface. Their vegetation is *Lepidio-Camphorosmetum annuae*. Its subassociations are indicating further differences in relief, alkalinity degree, resp. soil moisture.

4. In the deeper zones of hill ridges and berm bottoms there can be measured lower total salt and alkalinity values: the desiltable granule fraction of the surface-soil layers is larger than 80 p. c. At the same time, the content of soil moisture is treble (July, 1965). These are as before, in the future too, solonchak, resp. solonchak-solonetz. *Lepidio-Puccinellietum* occurs, as well. Its subassociations are the result of further changes in alkalinity and water content.

5. Under similar conditions of hard soils, in meadow grounds having a decreasing relief, resp. a low alkalinity degree, in the layers of which the salt accumulation does not reach even the alkalinity threshold in ecological sense, the percentage of soil moisture is increased owing to the flux of layer water. These marshy meadows are formed by the associations of *Festucetum pratensis, Astero-Agrostetum,* resp. of *Agrosti-Alopecuretum danubiale.*

B. In soils formed on clayey mud, resp. clay:

1. In meadow chernozem soils of higher relief in whose profile the fraction of granule size with a diameter smaller than 0,05 mm is about 80 percent, and the values of total salt, resp. soda alkalinity do not reach the alkalinity threshold in ecological sense, there occurs *Achilleo-Festucetum pseudovinae typicum*, without Euhalophytic species.

2. Under low relief conditions, the soil here has remained hard as before but close to the soil surface a solonetz level has developed. In these meadow solonetz of solonchak character becoming more and more steppe-like, the distribution of *Artemisio-Festucetum pseudovinae* can be observed.

3. In the solonchak-like meadow solonetz that developed on the bottoms of berms zonally and on the berms secondarily, extrazonally, high salt concentration is combined with low soil-moisture content: the vegetation is *Camphorosmetum annuae.* — In case of lower total salt and more favourable soil moisture *Puccinellietum limosae* occurs, with subassociations referring to transitory soil-ecological conditions.

4. In meadow soils with salt in depth, in the profile of which the two clay fractions are prevailing in the desiltable part, alkalinity occurs at the most in the deeper strata. Its most distributed marshland association is *Agrosti-Alopecuretum.*

In the deepest zone the two clay fractions are already forming 80 percent of the desiltable part of the soil layers, without any considerably salt content. There occur here the glycophilic species combinations of *Agrosti-Beckmannietum* demanding good water supply for the whole year. — In the same zone, as well as in the shore-zone of the lake, there is a salt marsh of alkali soil where *Bolboschoenetum maritimi continentale* is dominant.

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